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Better analysis and depiction of monsoon systems through satellite microwave remote sensing

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Abstract : In this study, various algorithms developed by global community have been applied to DMSP-SSM/I data Those algorithms which were found most suitable and appropriate have been used for the analysis and proper depiction of monsoon systems over the Indian region It is found that prior to the formation the monsoon depressions, there was strengthening of surface wind speed to the south of the low pressure area This wind speed was of the order of 12–15 ms^{-1}. The strengthening of wind speed was in association with the low-level jet present over that region Higher values of integrated water vapour (60–70 kg m^{-2}) were observed over the central and head Bay throughout the life cycle of monsoon depression Highest values of integrated cloud liquid water (0 7 kg m^{-2}) were found to be associated with major convective activity in the southwest sector of the monsoon depression Windspread precipitation (2–16 mm hr^{-1}) was found to be associated with low pressure system over the northwest Bay and the precipitation was further found to be concentrated more in the southwest sector of the monsoon depression with maximum precipitation rates of the order of >20 mm hr^{-1} Results of our study suggest that estimated geophysical parameters obtained from SSM/I data can be used with some confidence as an input to various weather forecast models.

Keywords . DMSP-SSM/I, geophysical parameters, depression

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1. Introduction

In the recent years, remote sensing of the atmospheric systems from the space has been enhanced from variety of microwave sensors. Most notable among these sensors is Special Sensor Microwave/Imager (SSM/I), a multichannel microwave radiometer with imaging capability, onboard American defense satellite series DMSP. The microwave imager provides a wealth of information about geophysical parameters such as integrated water vapour, integrated cloud liquid water, surface wind speed and precipitation rates. In this study, the observational capability and potential use of DMSP-SSM/I in the context of the monsoon systems is discussed. Some of the algorithms developed by the world community in the recent years for the retrieval of the geophysical parameters have been examined and those found most useful over the Indian region have been used in this study.

It is observed from the earlier works [1–4] that SSM/I data have been used mostly for studying the large scale aspects of monsoon circulation. These data have not been exploited so far, in detail, for studying monsoon systems over the Indian region. Therefore, in this study, characteristic features associated with different stages of monsoon depression are brought out.

2. Data

The SSM/I brightness temperature measurements at four frequencies *viz.* 19.35, 22.235, 37 and 85.5 GHz are used for monitoring the aerial coverage of monsoon systems, particularly lows and depressions over the Bay of Bengal during 1991-95. Daily weather summaries obtained from Indian Meteorological Department are used for selecting the synoptic situation over the Indian region for the life cycle of monsoon systems. DMSP and INSAT satellite imagery are used to locate and to mark the advancement of monsoon systems over the Indian region. ECMWF surface and upper air charts are used to identify and inspect the surface pattern and upper air circulation associated with monsoon systems.

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3. Methodology

The passive microwave emissivity of the ocean surface varies in response to deformation to it causing changes in its brightness temperature. These changes in brightness temperature are measured by SSM/I, and can be analysed to retrieve wind speed over the oceanic regions. There are several surface wind speed algorithms. The recent ones are (i) Goodberlet *et al* [5], (ii) Goodberlet and Swift [6], (iii) Schluessel and Luthardt [7] and Petty [8]. The estimated surface wind speed obtained from these algorithms were compared with the surface wind speed of Minicoy island station because it has the lowest height among all the island stations over the Indian seas. It is found that Petty's algorithms suits best with all statistical tests Hence, this algorithm is used in this study.

Algorithms for passive microwave retrieval of integrated water vapour have been well established and documented in the literature since the middle of 1970s [9]. For SSM/I, however, there have been number of recent developments. The following algorithms have been considered for this study *i e.* (i) Alishouse *et al* [10], Petty and Kartsaros [11], Schluessel and Emery [12] and Lojous *et al* [13]. Estimated integrated water vapour obtained from these algorithms are compared with the integrated water vapour obtained from radiosonde data of Minicoy and Portblair island stations. Schluessel and Emery's algorithm [12] was found to give the best description of integrated water vapour over the Indian region.

Five recent algorithms for integrated cloud liquid water namely (i) Alishouse *et al* [13], (ii) Hargens *et al* [14], (iii) Petty [15], (iv) Wentz [16] and (v) Weng and Grody [17] have been considered for this study. The major improvement of Weng and Grody's algorithm over many others are due to (a) it detects cloud liquid water in optically thin stratus and low level clouds very well, (b) it measures cloud liquid water in highly convective clouds, (c) cloud liquid water derived from this algorithm agree well with that derived using ground based measurements. Hence we have used algorithm of Weng and Grody in our study. Figure 1 shows SSM/I-derived cloud liquid water distribution for monsoon depression during 22–27 July, 1992.

Four recent algorithms for precipitation rates developed by different researchers namely (i) Olson, (ii) Berg, (iii) Petty and (iv) Smith *et al* [18] have been examined in our study. The details of the algorithms by Olson, Berg and Petty can be seen in Wilheit *et al* [19]. Of these, the algorithm developed by Smith *et al* [18] is found to be most suitable over the Indian region because of the following reasons : (a) in this technique the error caused by spatial and temporal variations of surface temperature, emissivity and atmospheric effects are minimised by modelling non-raining brightness temperatures with half degree latitude and half degree longitude region based on statistics of satellite data, (b) the algorithm is sensitive to light rainfall less than 0.5 mm hr^{-1} and shows large dynamic range of measuring heavy rainfall.

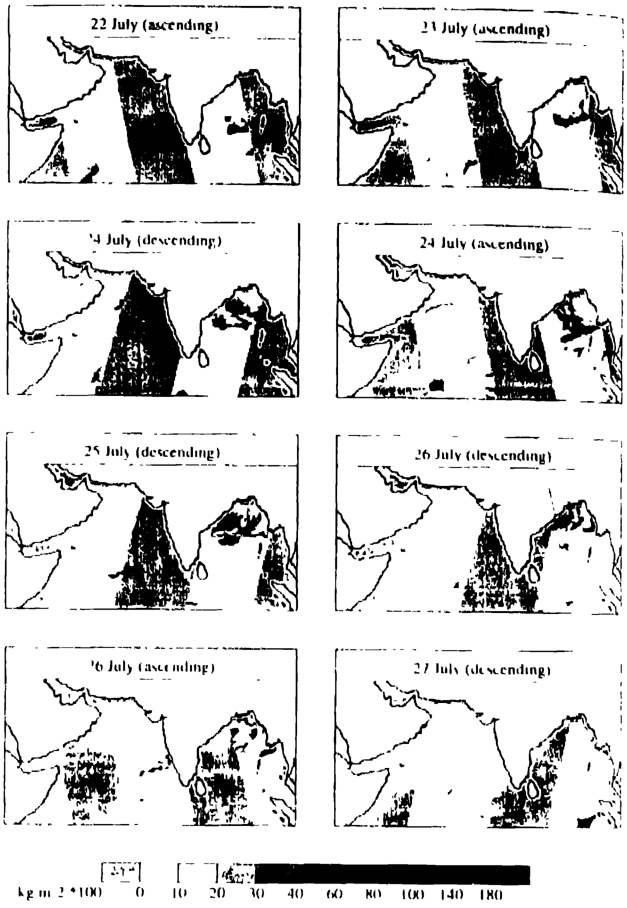

Figure 1. DMSP-SSM/I-derived cloud liquid water distribution for monsoon depression during 22–27 July, 1992

4. Results

The following salient features have been brought out based on the depression that formed over the Bay of Bengal during 22–27 July, 1992.

(i) The effect of low-level jet in modulating the strength of surface wind speed was observed prior to the formation of depression over the Bay of Bengal. This wind speed was of the order of 12–15 ms^{-1}.

(ii) Aerial coverage of higher values of the integrated water vapour (60–70 kg m^{-2}) was found to be more dominant in the southwest sector of the monsoon depression.

(iii) Higher values of the cloud liquid water were found to be well organised in the southwest sector of the monsoon depression with values >1.8 kg m^{-2}.

(iv) Precipitation rates were more in the southwest sector of the monsoon depression and they were of the order of 15–20 mm hr^{-1}.

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